

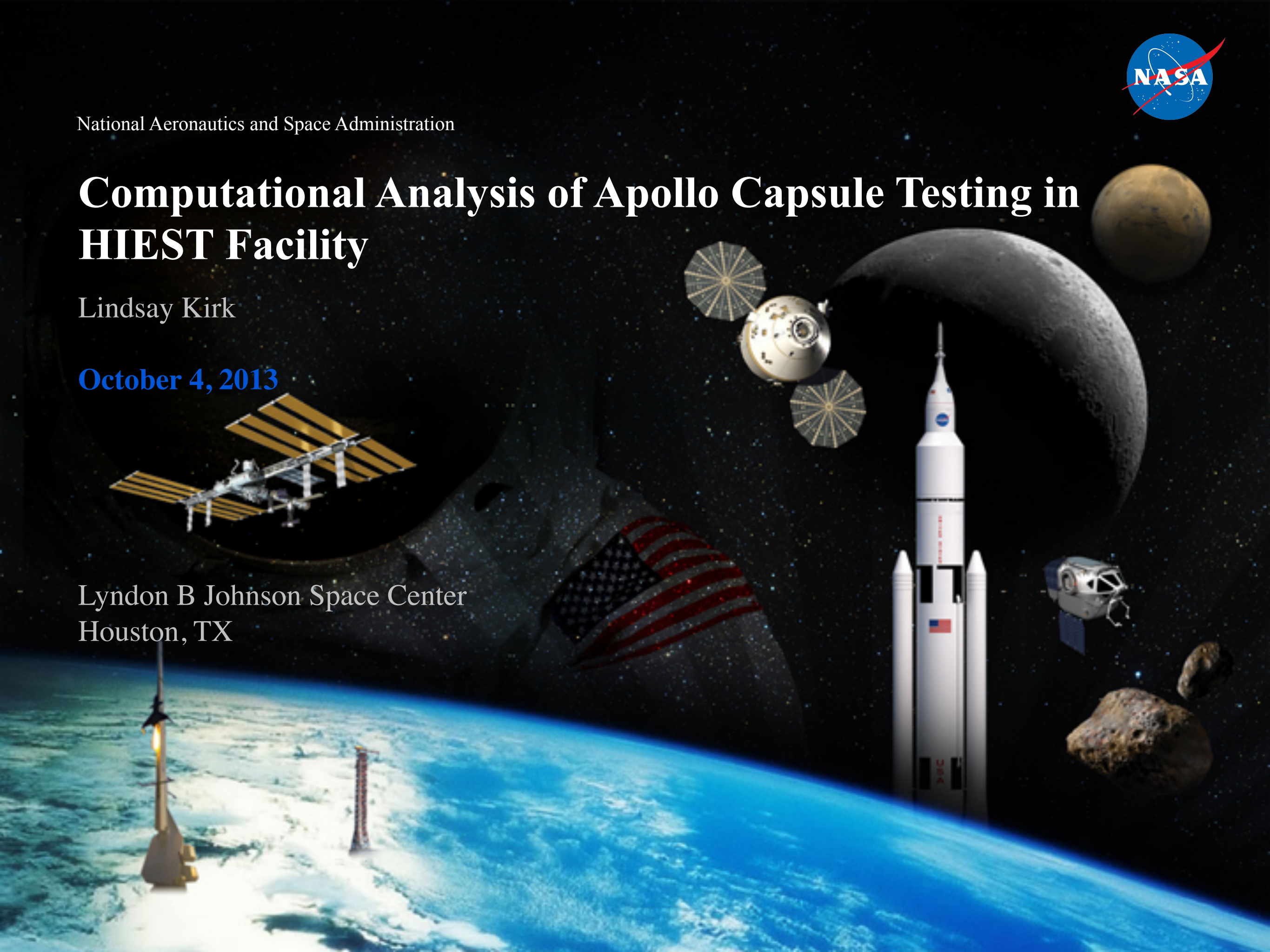
National Aeronautics and Space Administration

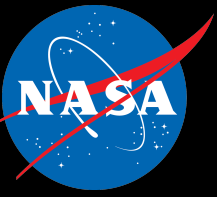
Computational Analysis of Apollo Capsule Testing in HEST Facility

Lindsay Kirk

October 4, 2013

Lyndon B Johnson Space Center
Houston, TX



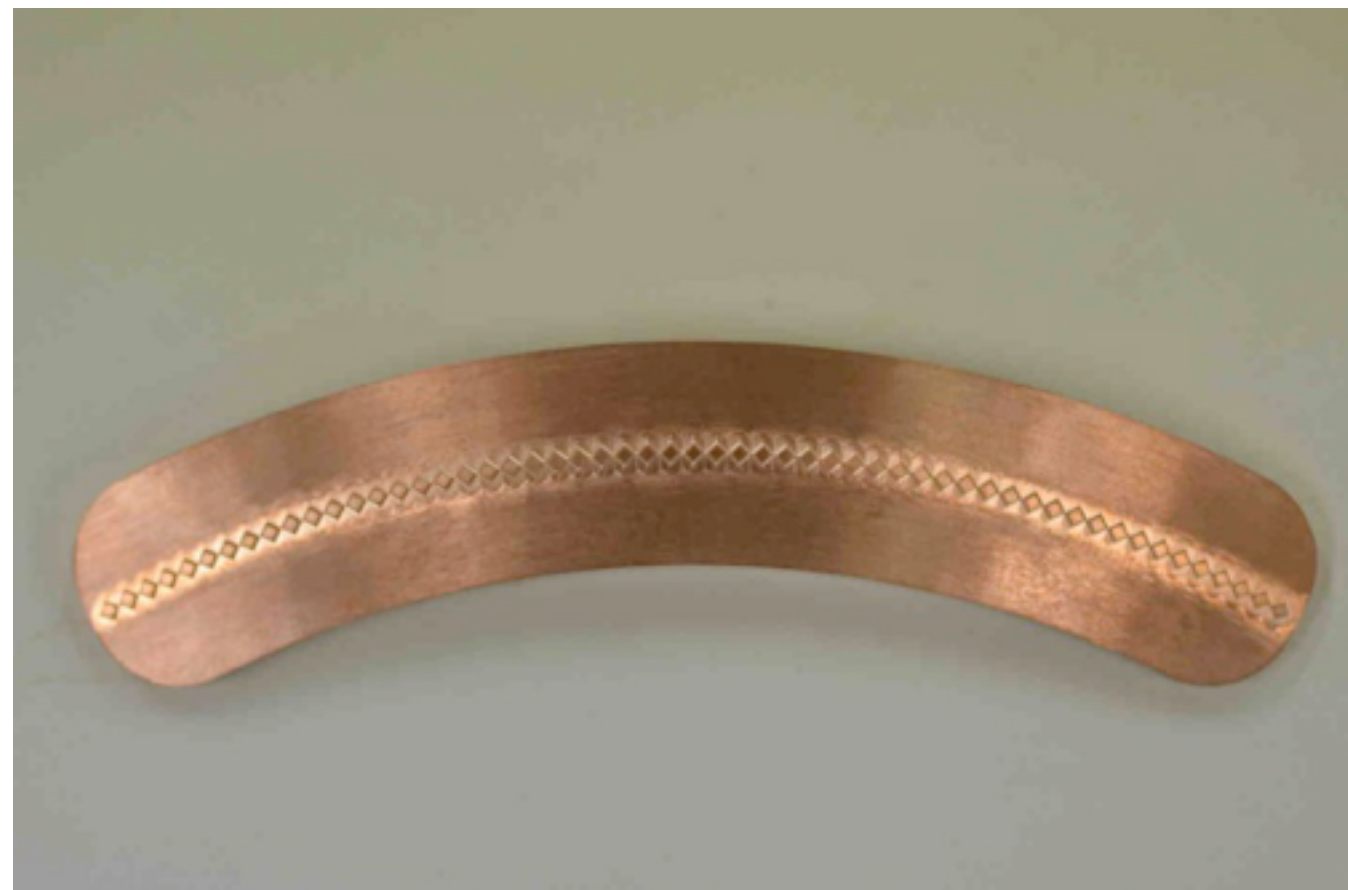
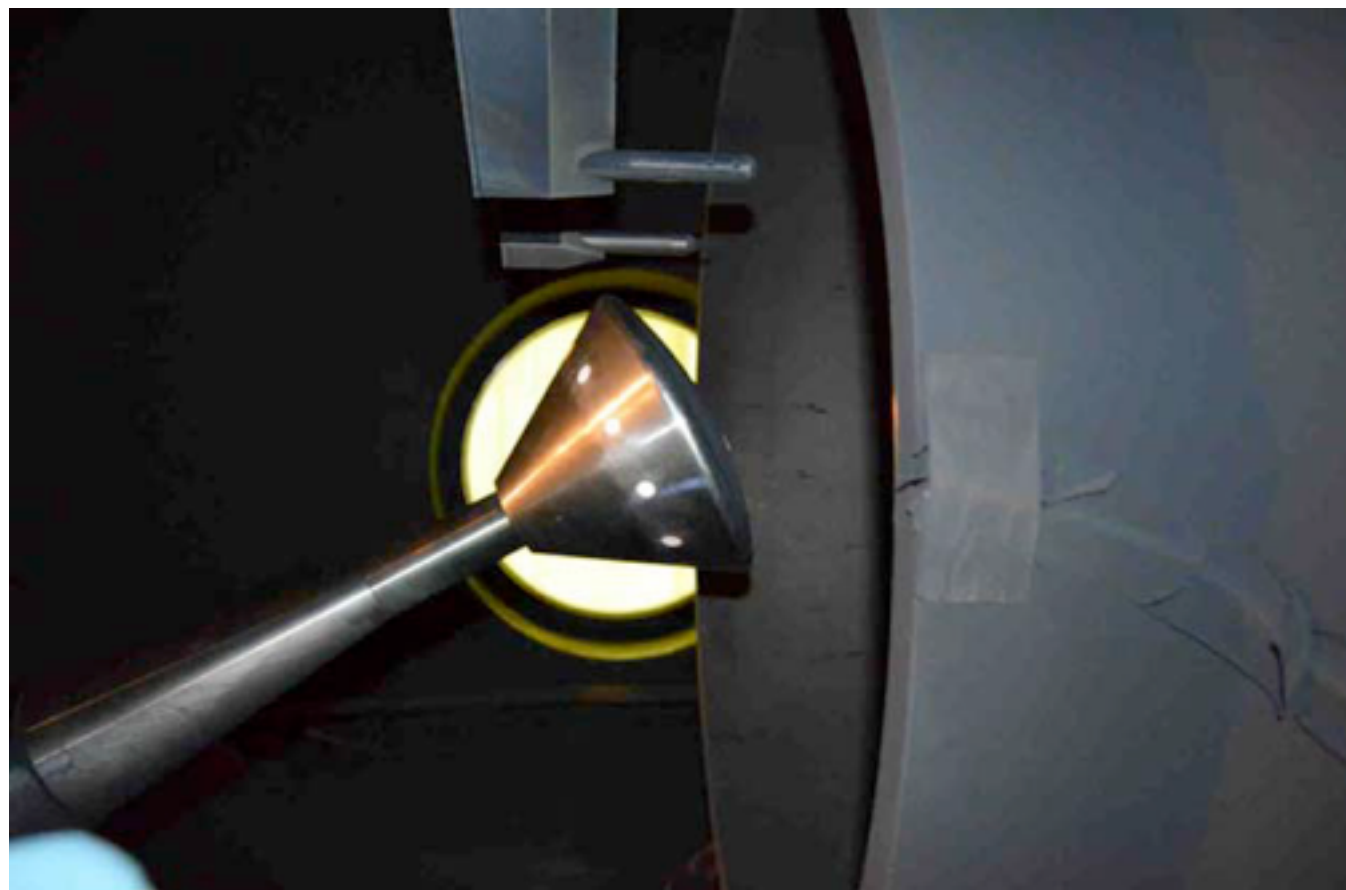


Overview

- **Background**
 - HIRST High Enthalpy Facility
 - Apollo Capsule Testing
- **Nozzle Computations**
- **Capsule Simulations**
 - Comparisons to Digitized Data
- **Results and Conclusions**

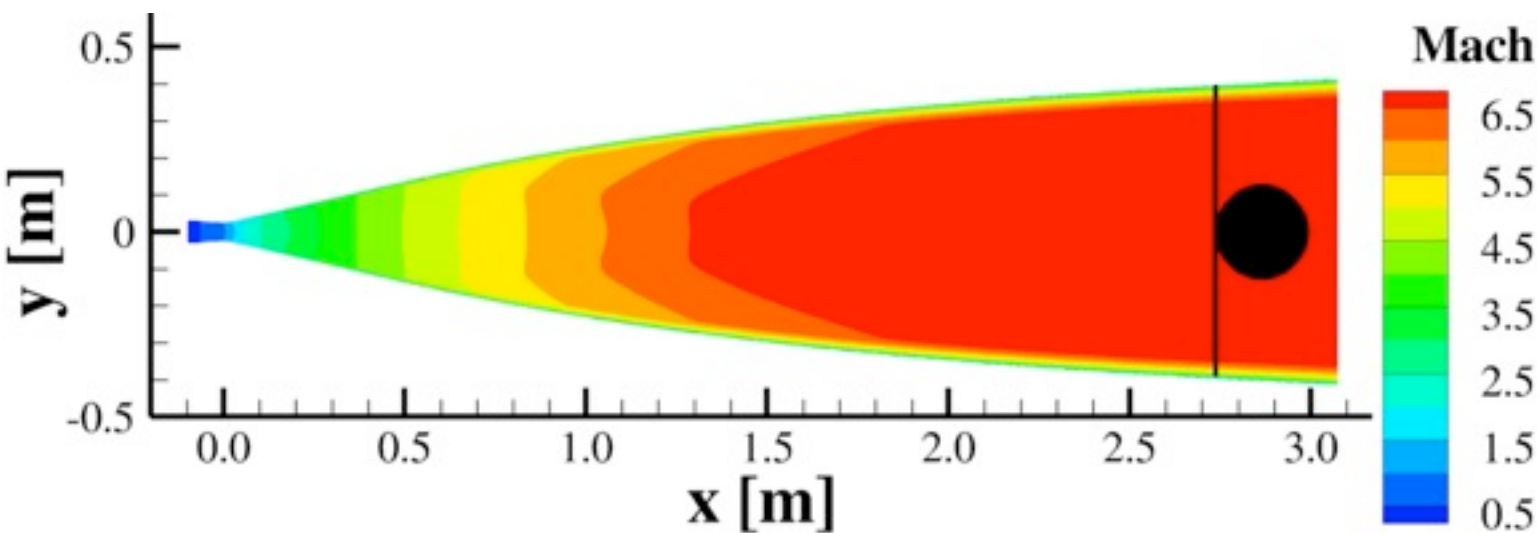
Background

- **250 mm diameter Apollo capsule being tested in JAXA's Hiest (High Enthalpy Shock Tunnel) facility.**
 - Smooth body and tripped configurations tested.
- **Nozzle chamber stagnation conditions provided for each run.**
 - Range of stagnation enthalpies from 3 MJ/kg to 20 MJ/kg and stagnation pressures from 12 MPa to 60 MPa tested in Hiest facility.
 - Additional chamber conditions (density, species mass fractions, etc.) computed using CEA equilibrium assumptions.

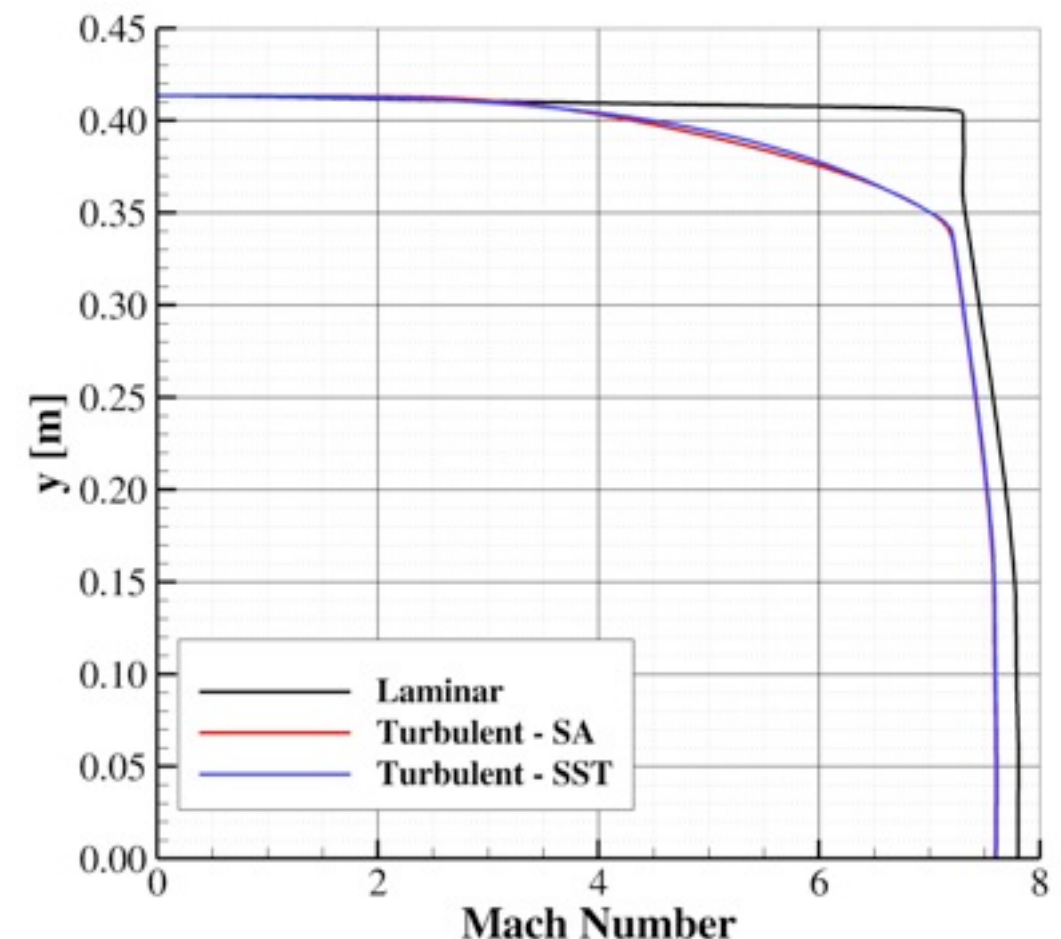


Nozzle Computations

- **Nozzle solutions run on an axisymmetric grid with stagnation conditions in plenum provided by test facility.**
 - Additional chamber conditions (density, species mass fractions, etc.) computed from CEA equilibrium assumptions.
 - Methodology is consistent with simulations completed in support of trip sizing study (R. Lillard).
- **Simulations were run with SST turbulence model.**
 - Other turbulence models provided similar results along nozzle centerline at model location.

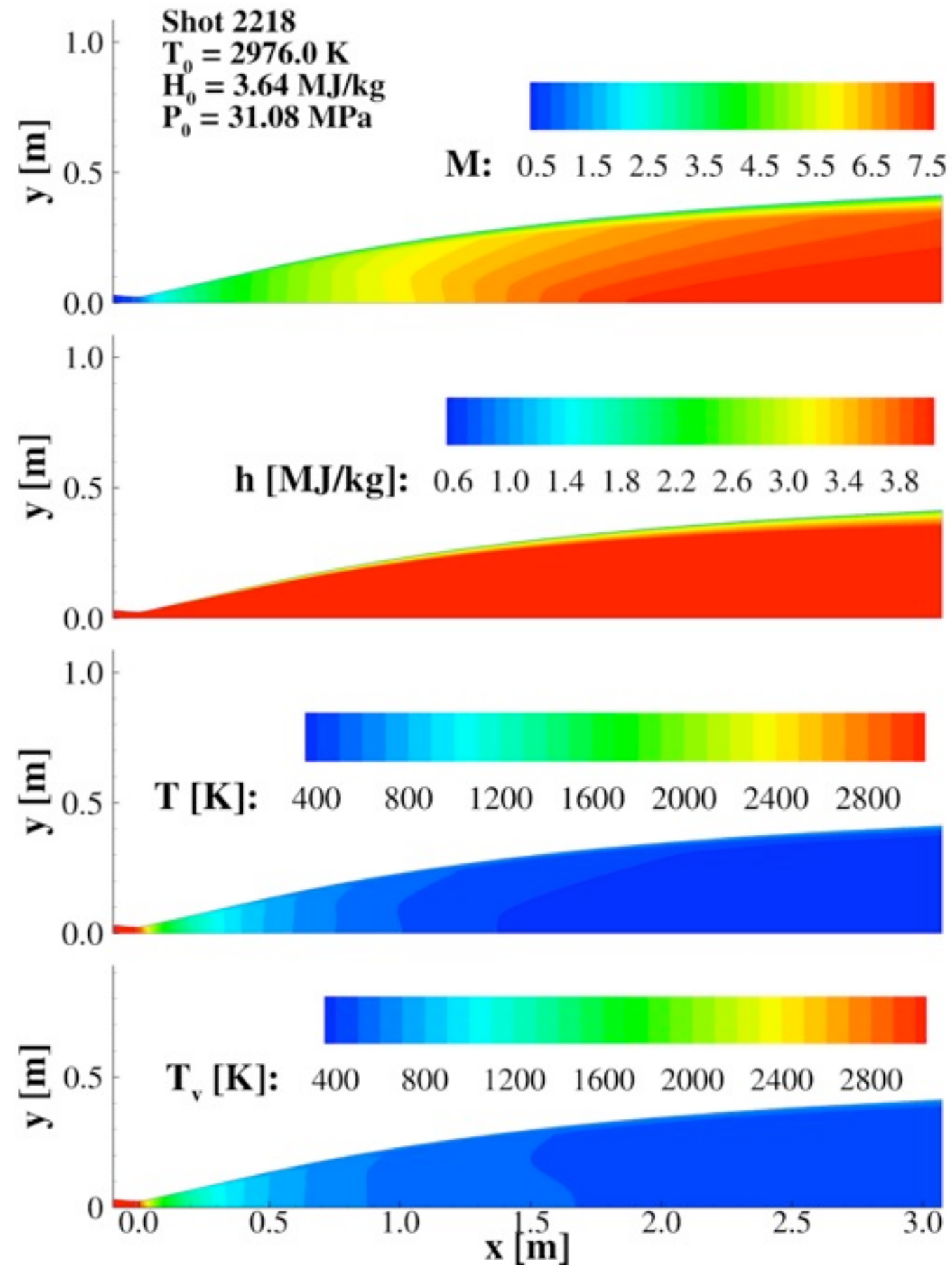
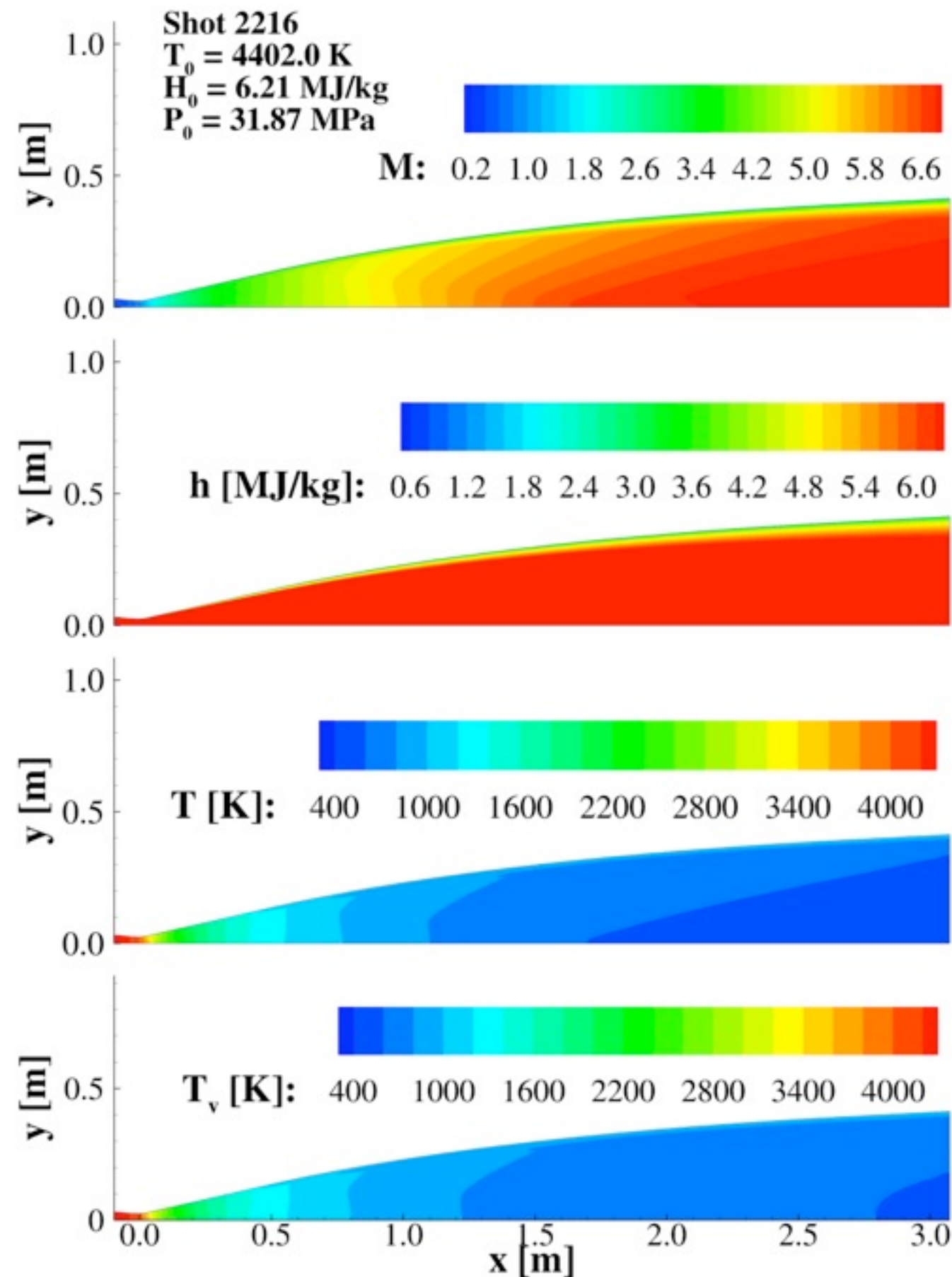


Assumed Model Location

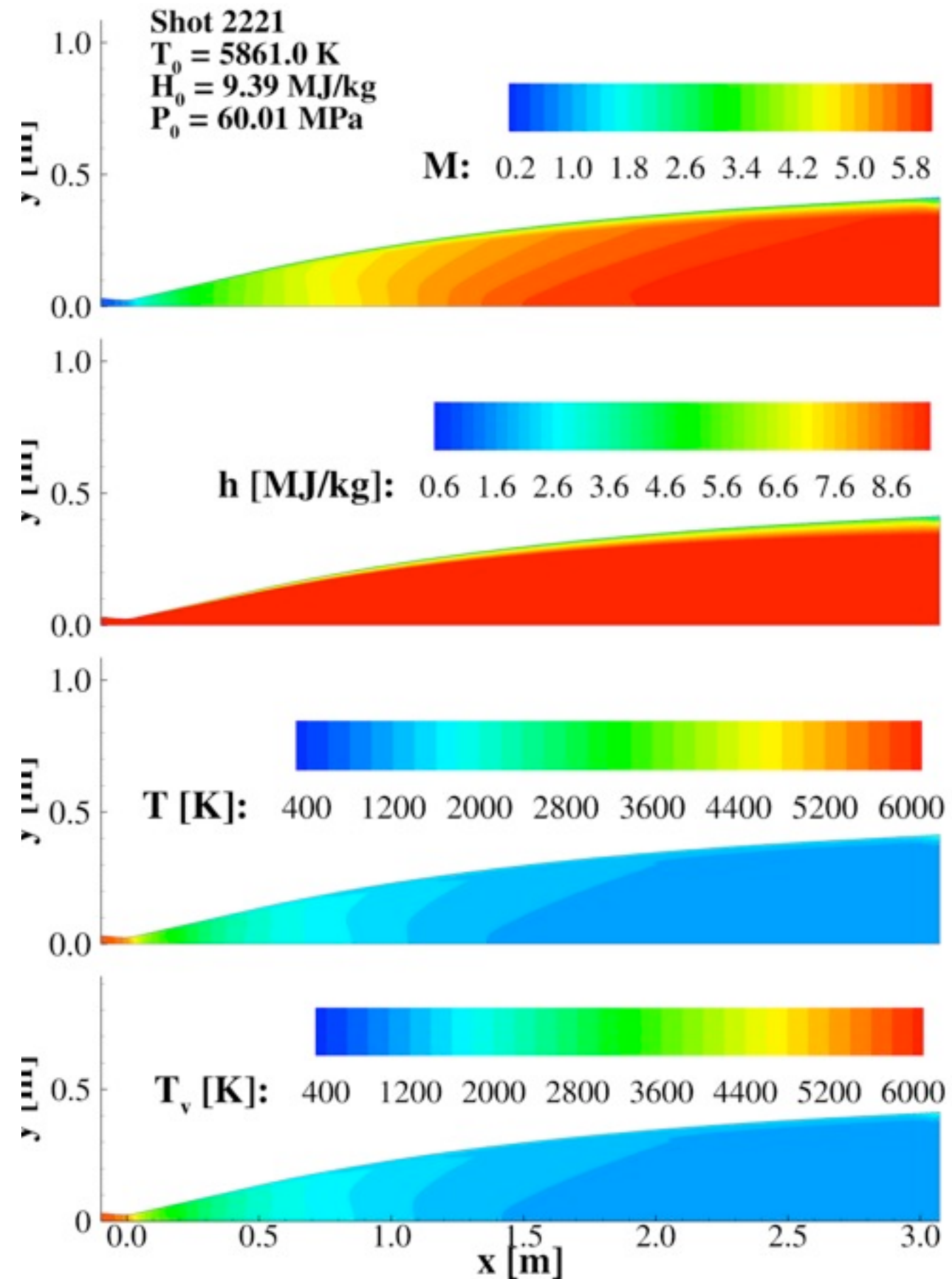
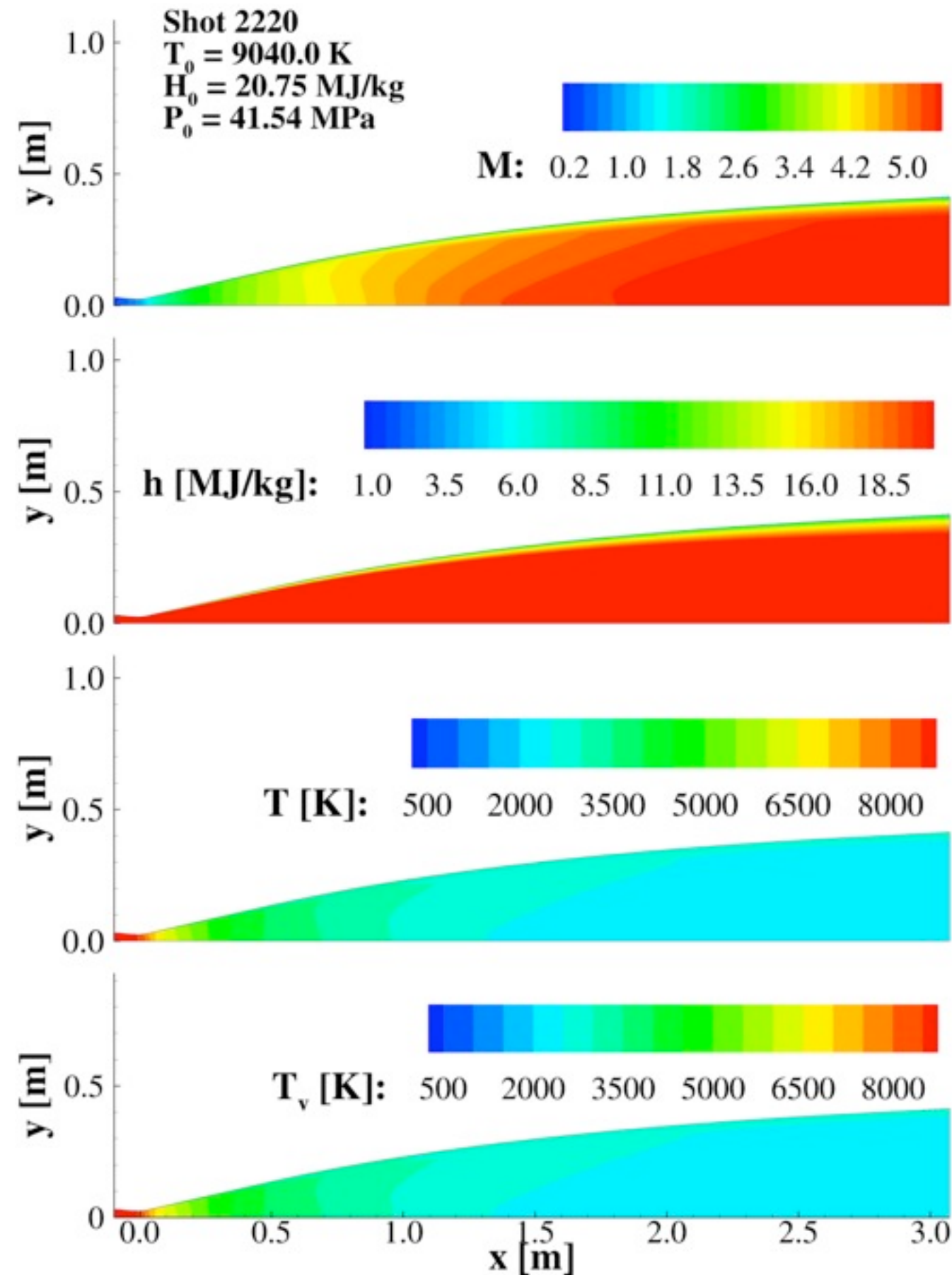


Mach number distribution at model location for different turbulence models.

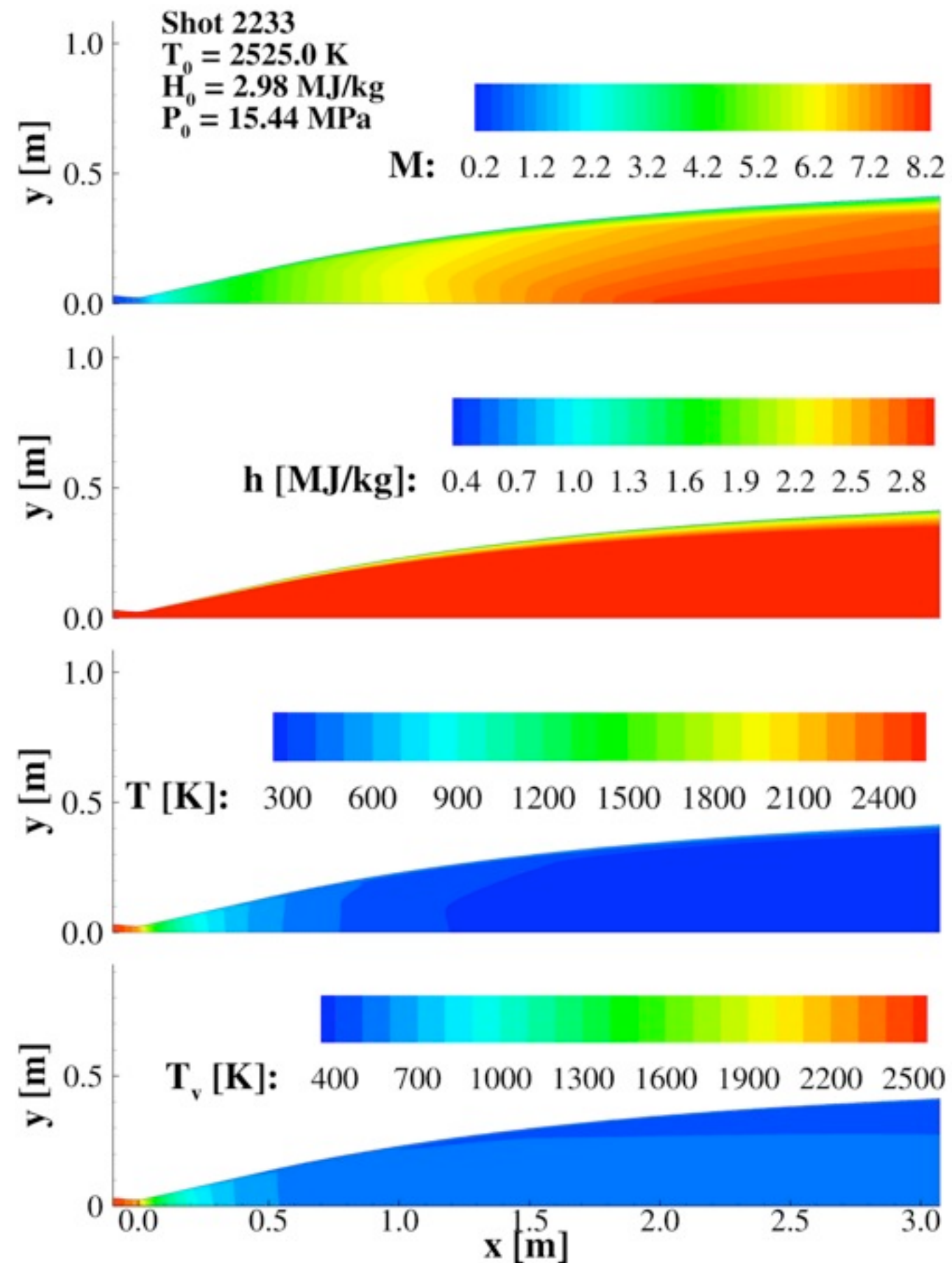
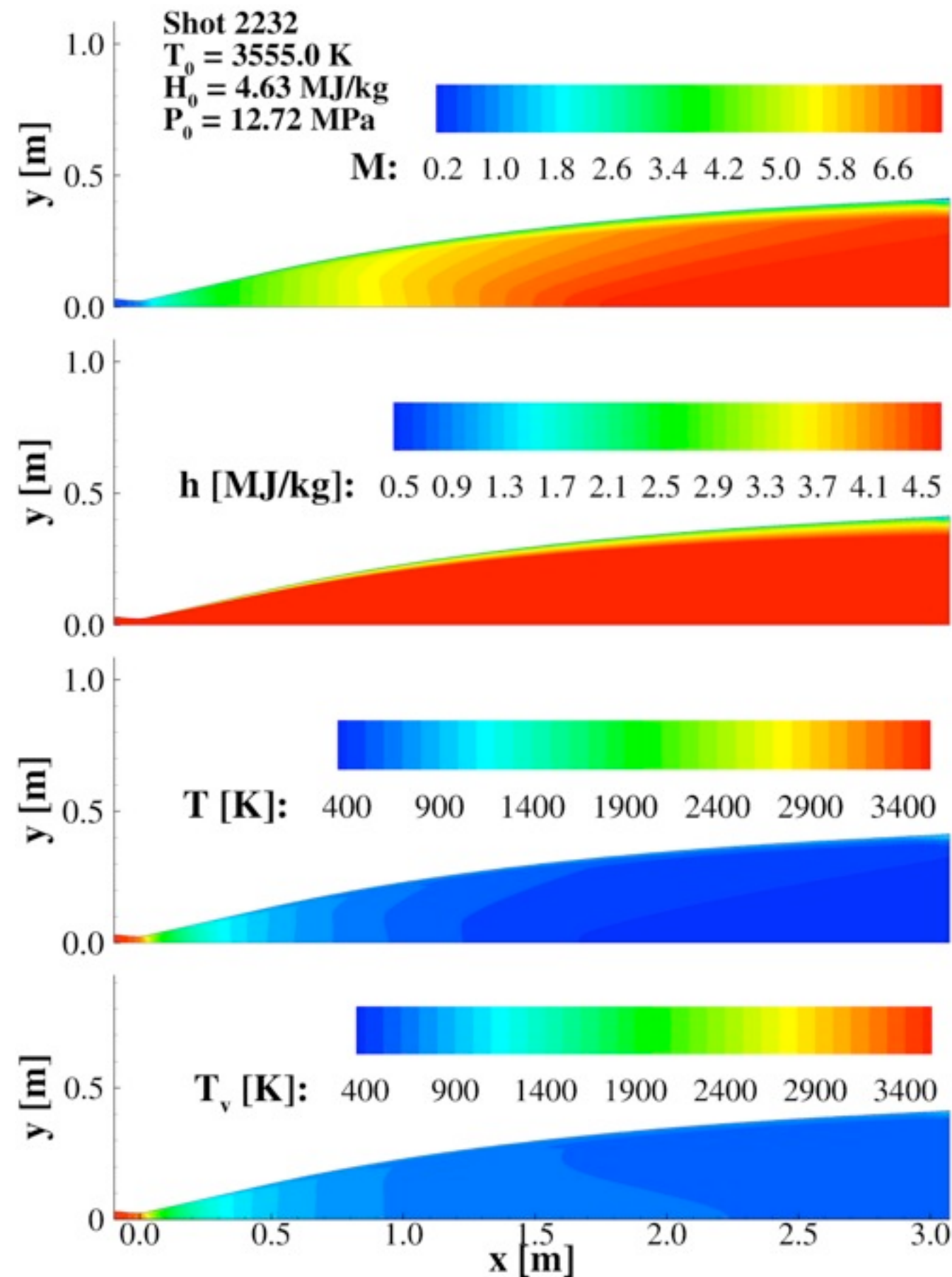
Nozzle Computations



Nozzle Computations

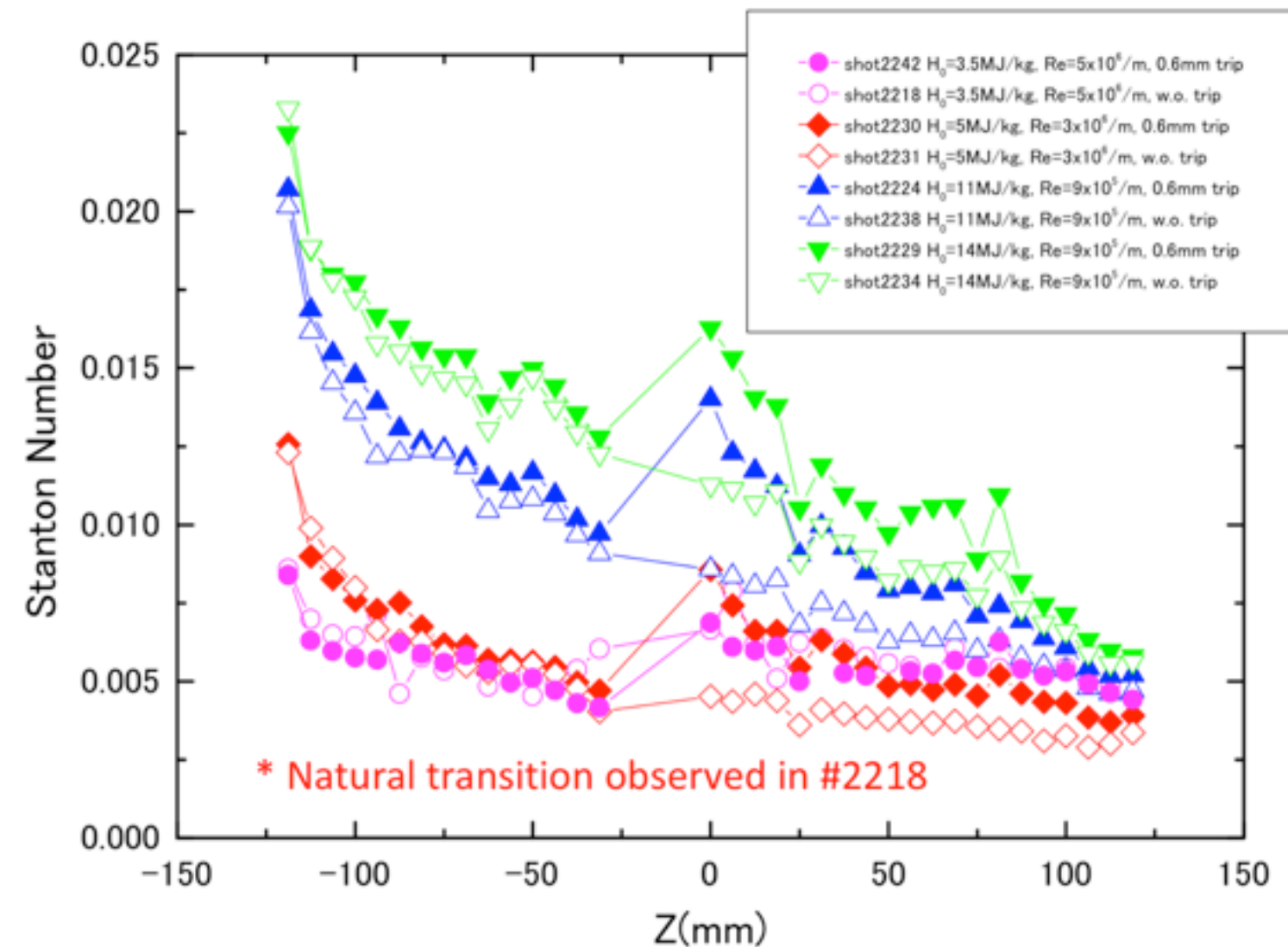


Nozzle Computations

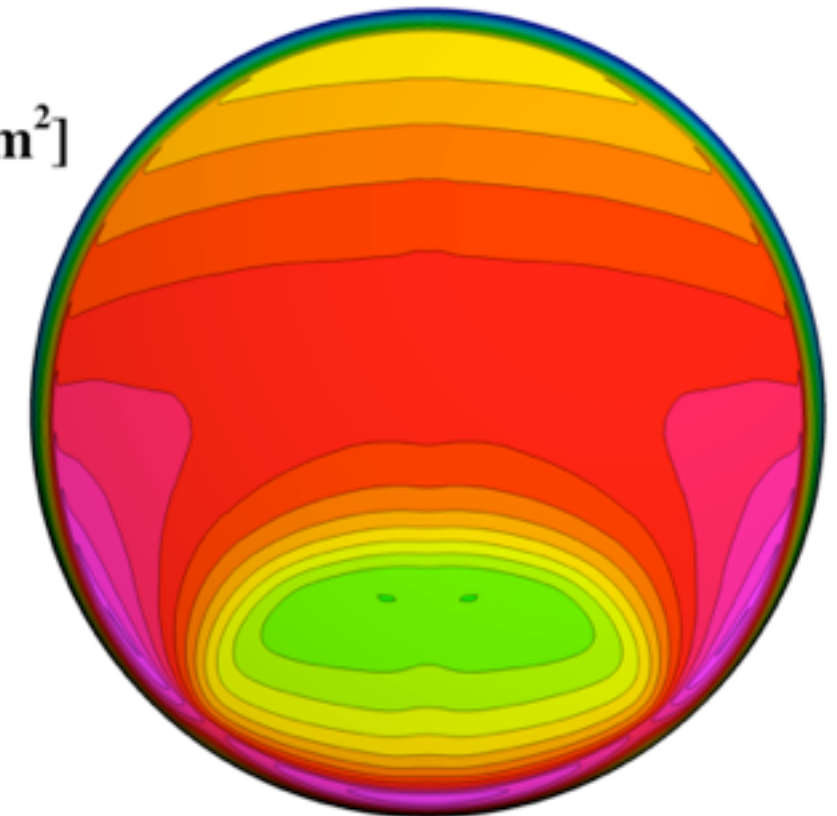
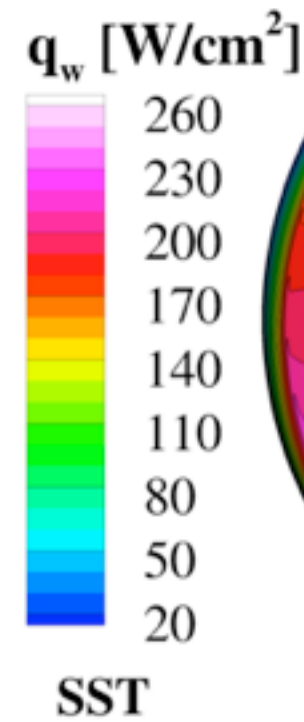
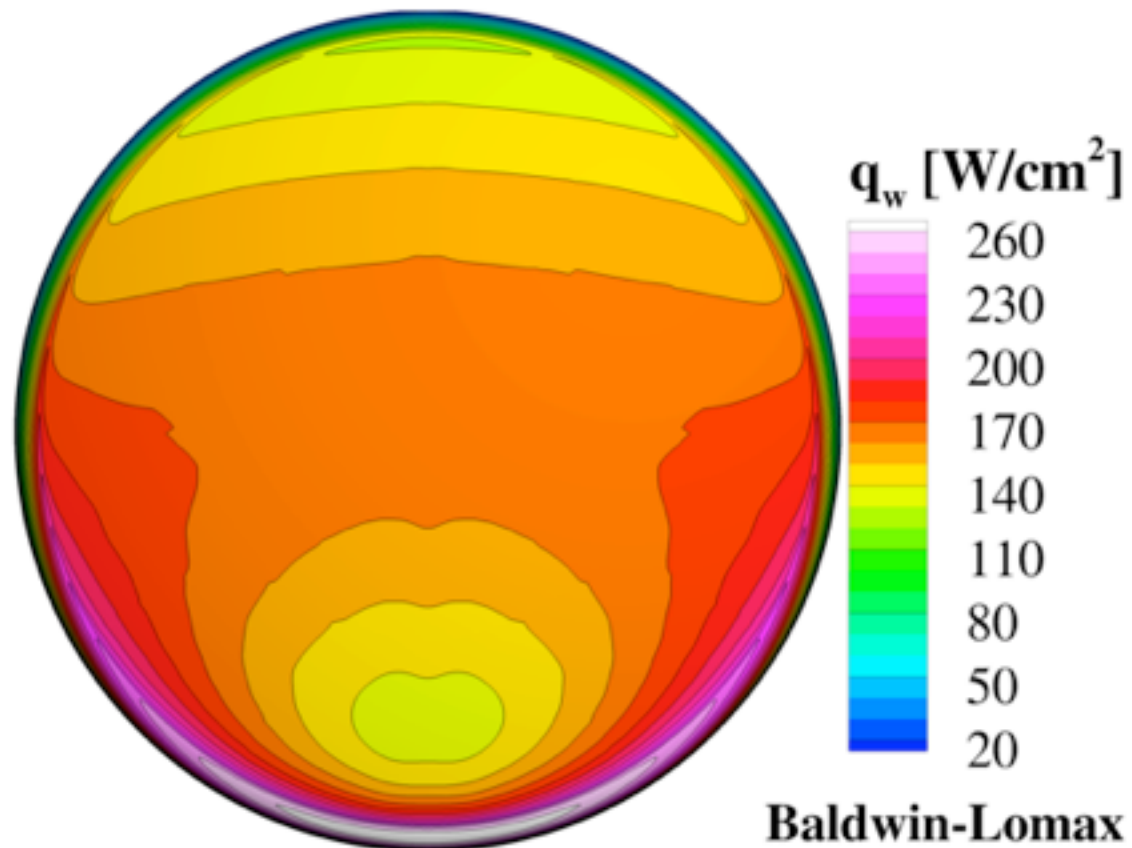
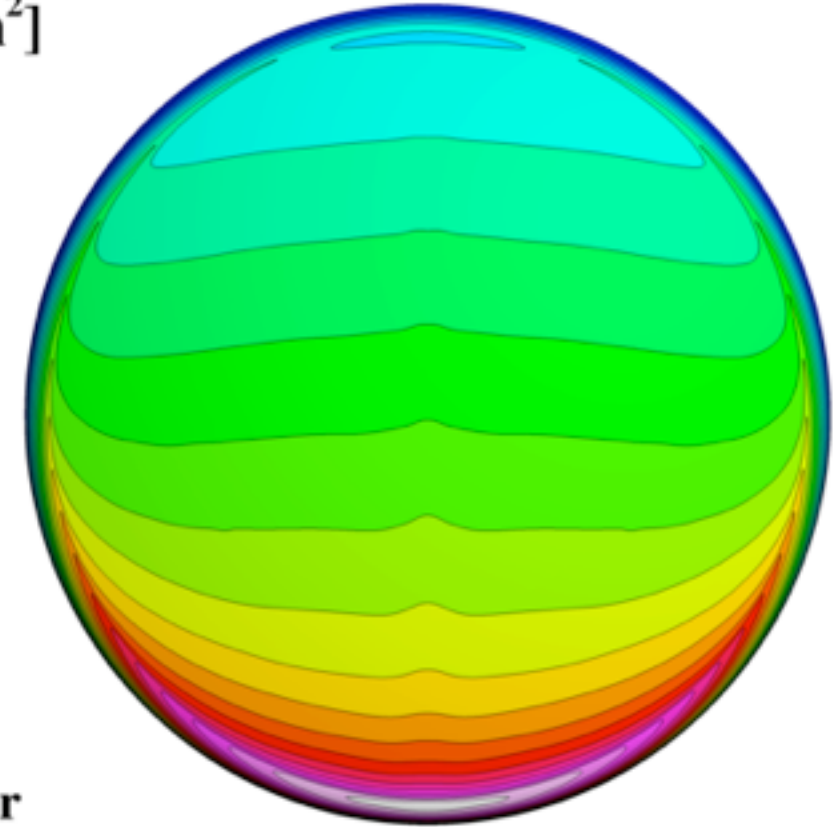
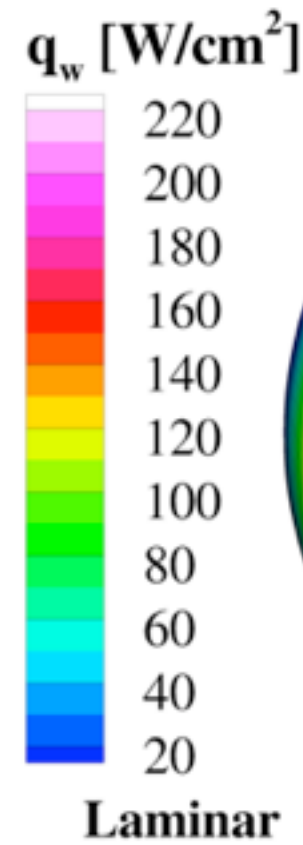
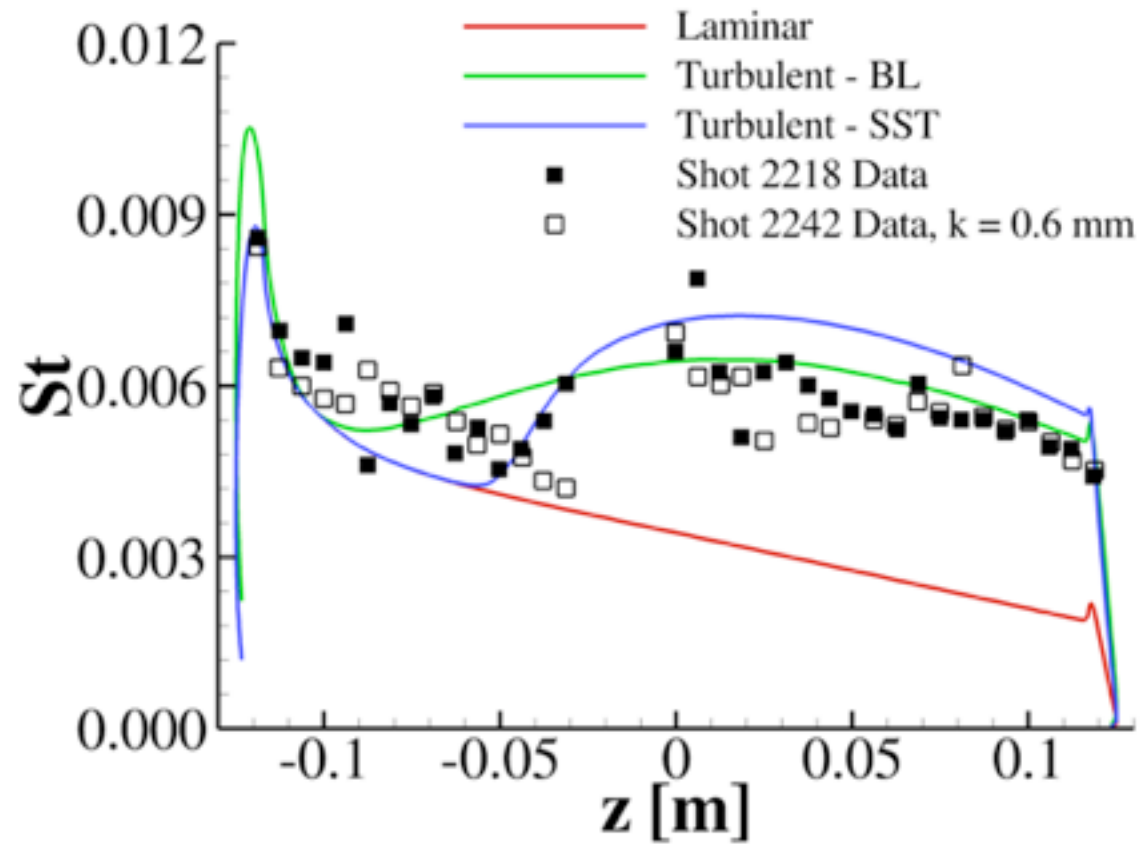


Capsule Simulations

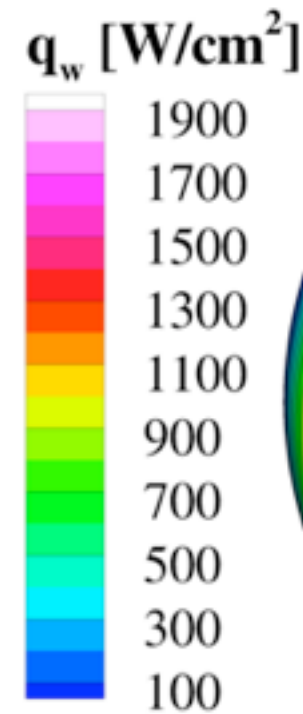
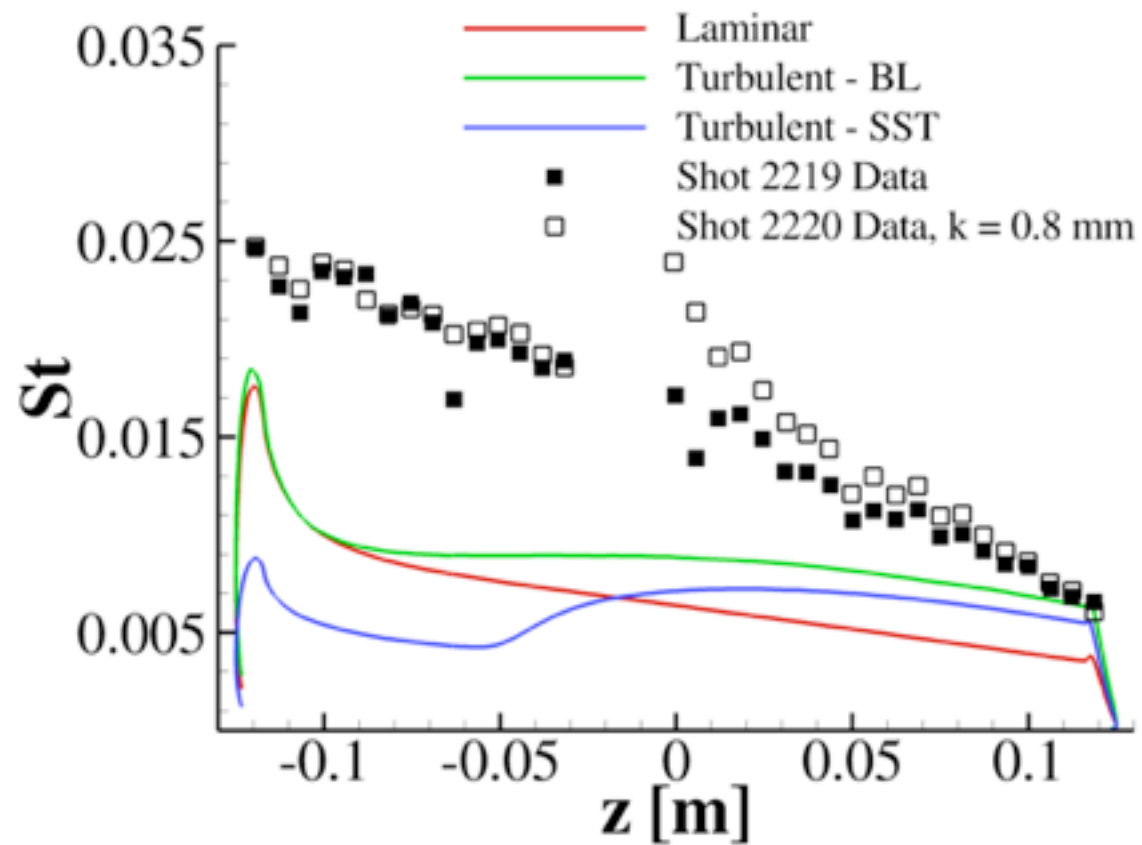
- **Assumed uniform freestream conditions extracted from centerline of nozzle simulations at capsule location in tunnel.**
 - Computed laminar and turbulent Baldwin-Lomax and SST simulations for each condition.
 - Surface currently modeled as non-catalytic and isothermal at room temperature conditions.
 - Plans include running catalytic wall conditions at higher enthalpy conditions.
 - Compared to data digitized from plots provided by JAXA with and without trips.



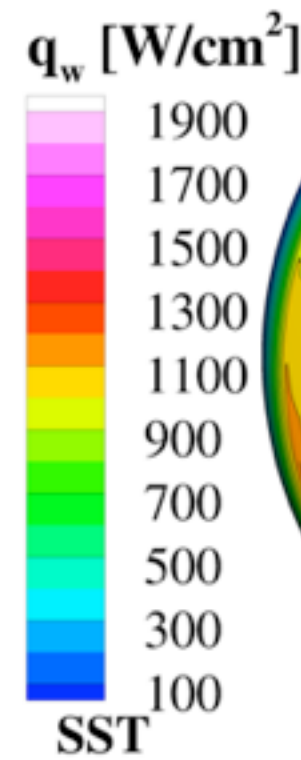
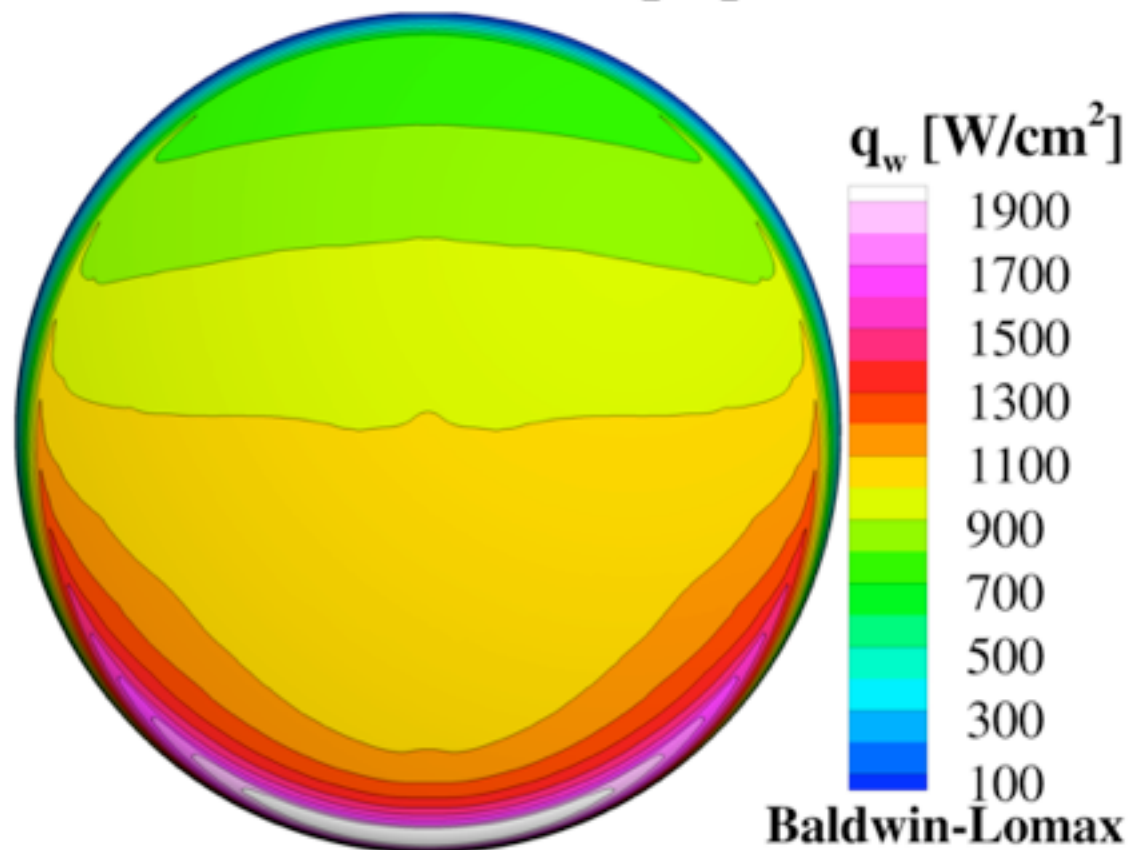
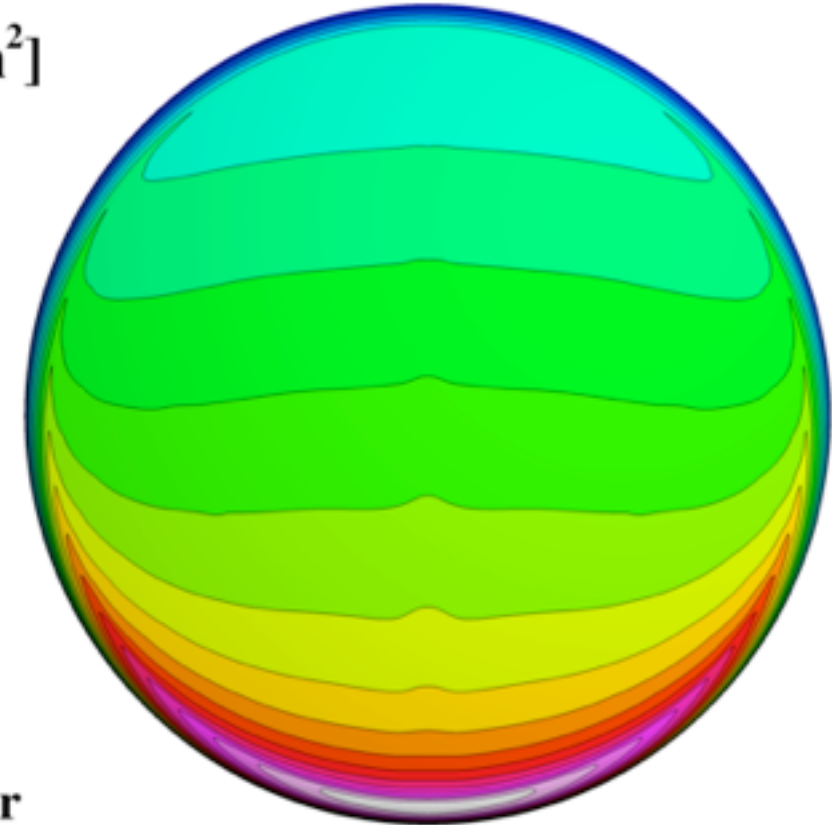
Shot 2218



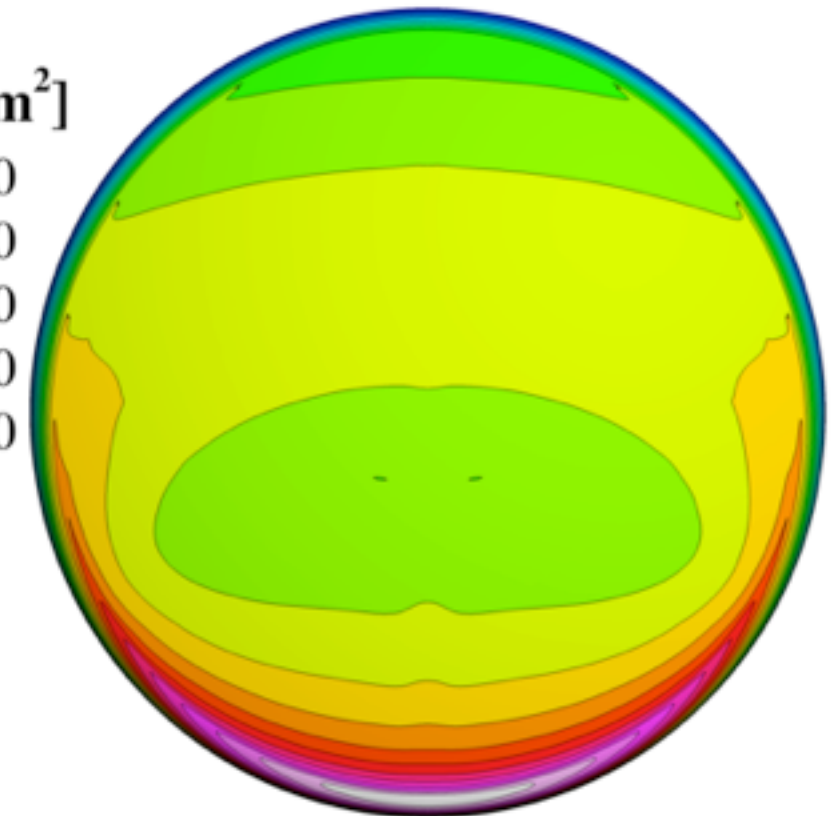
Shot 2220



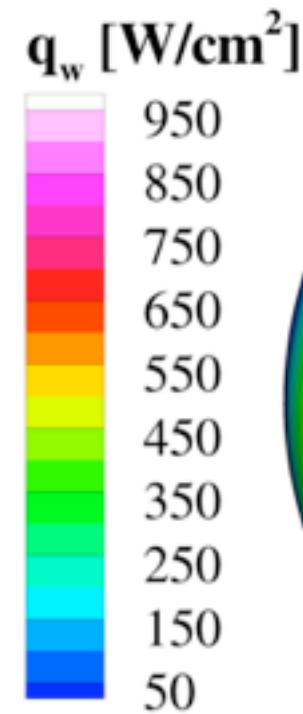
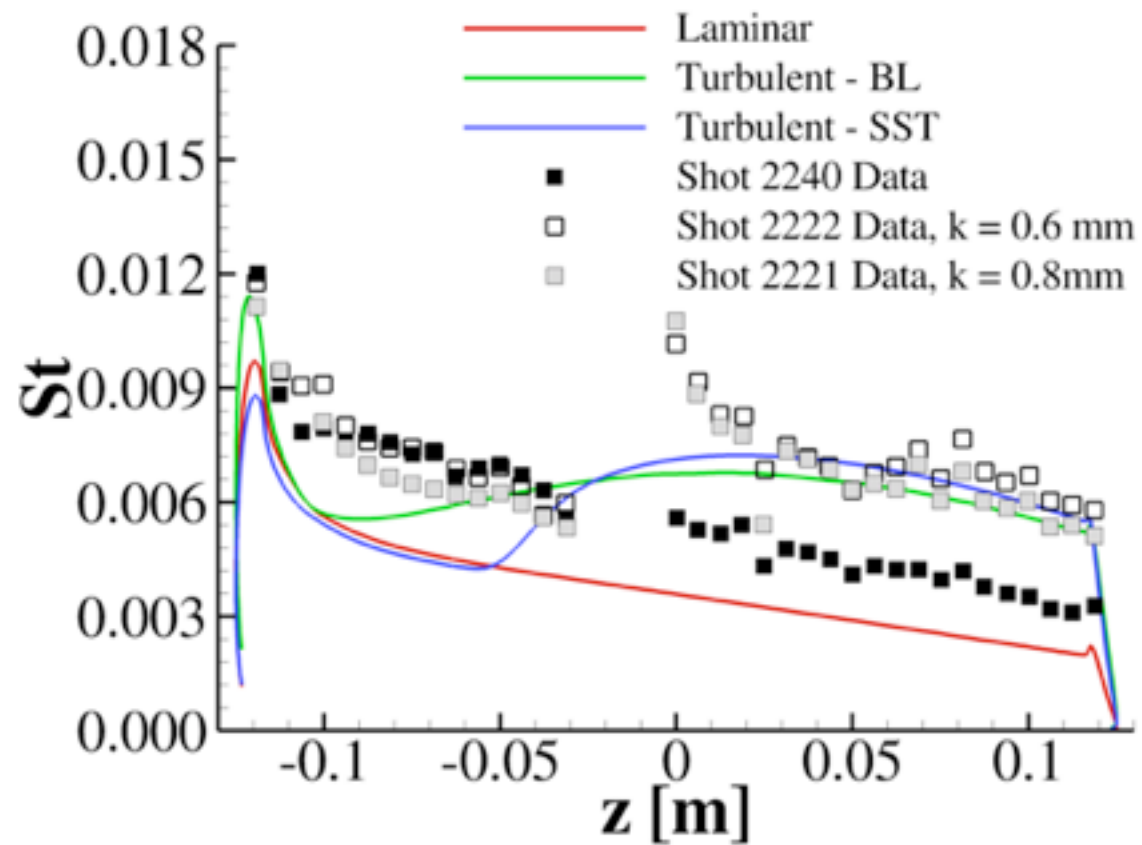
Laminar



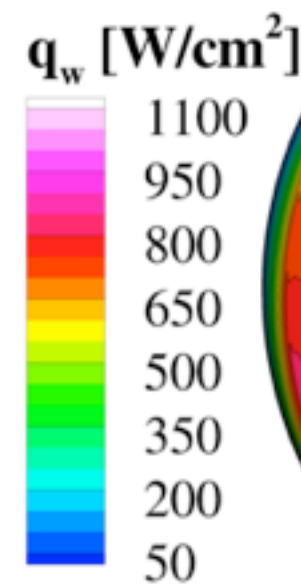
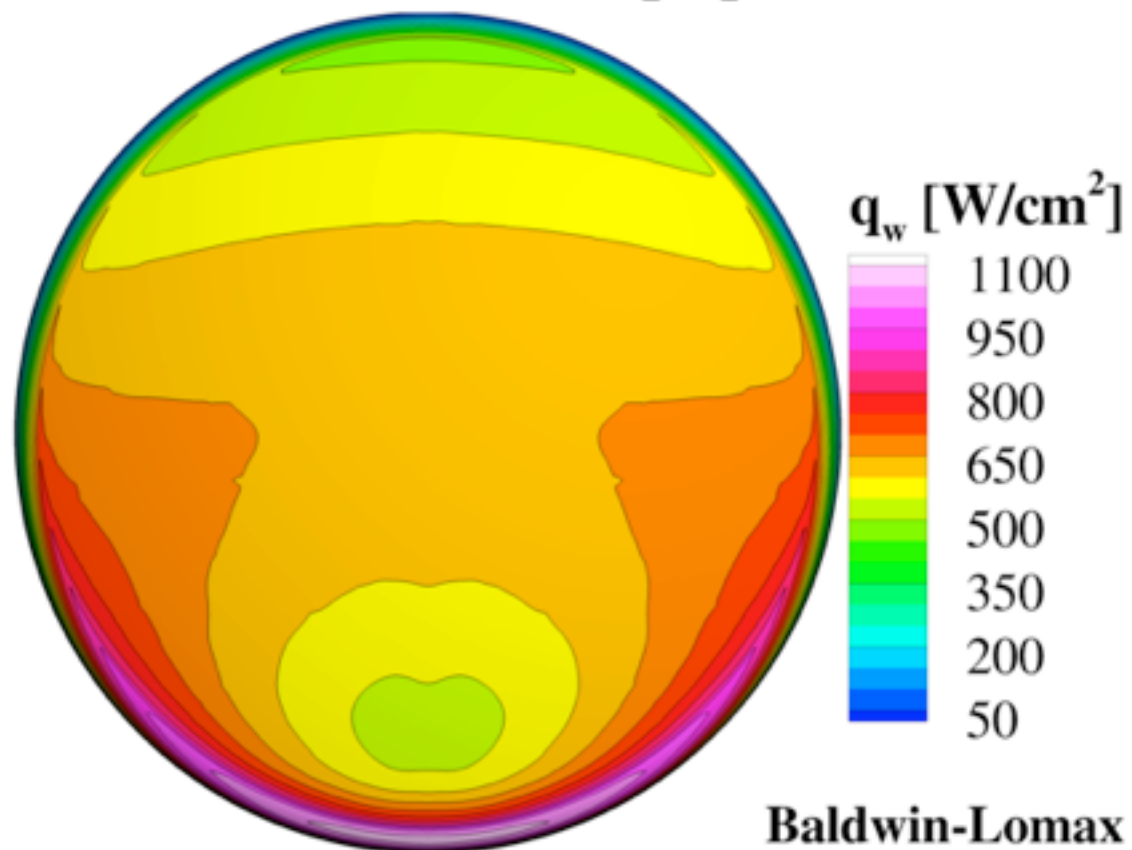
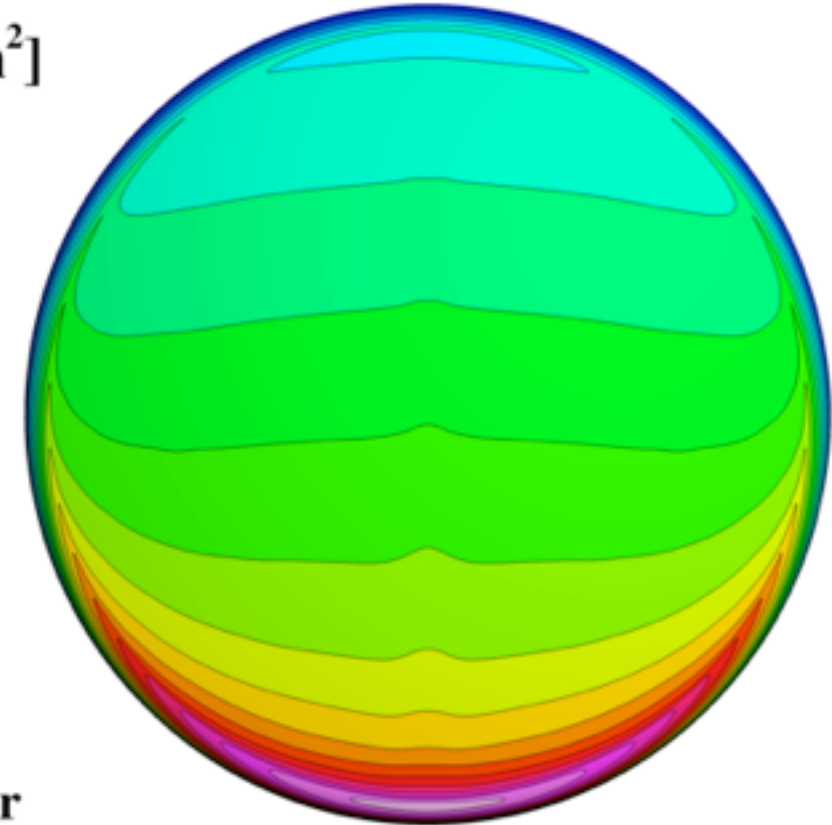
SST



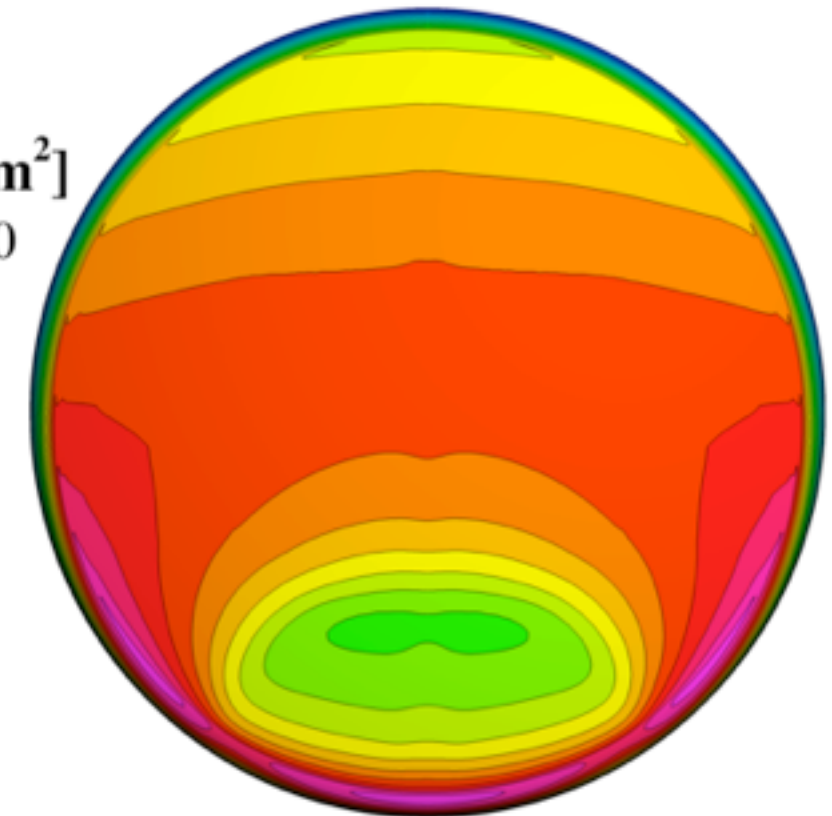
Shot 2221

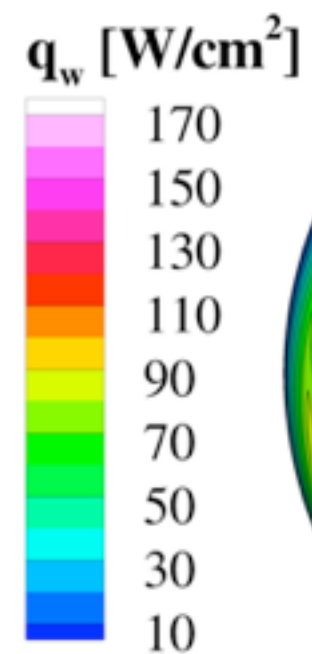
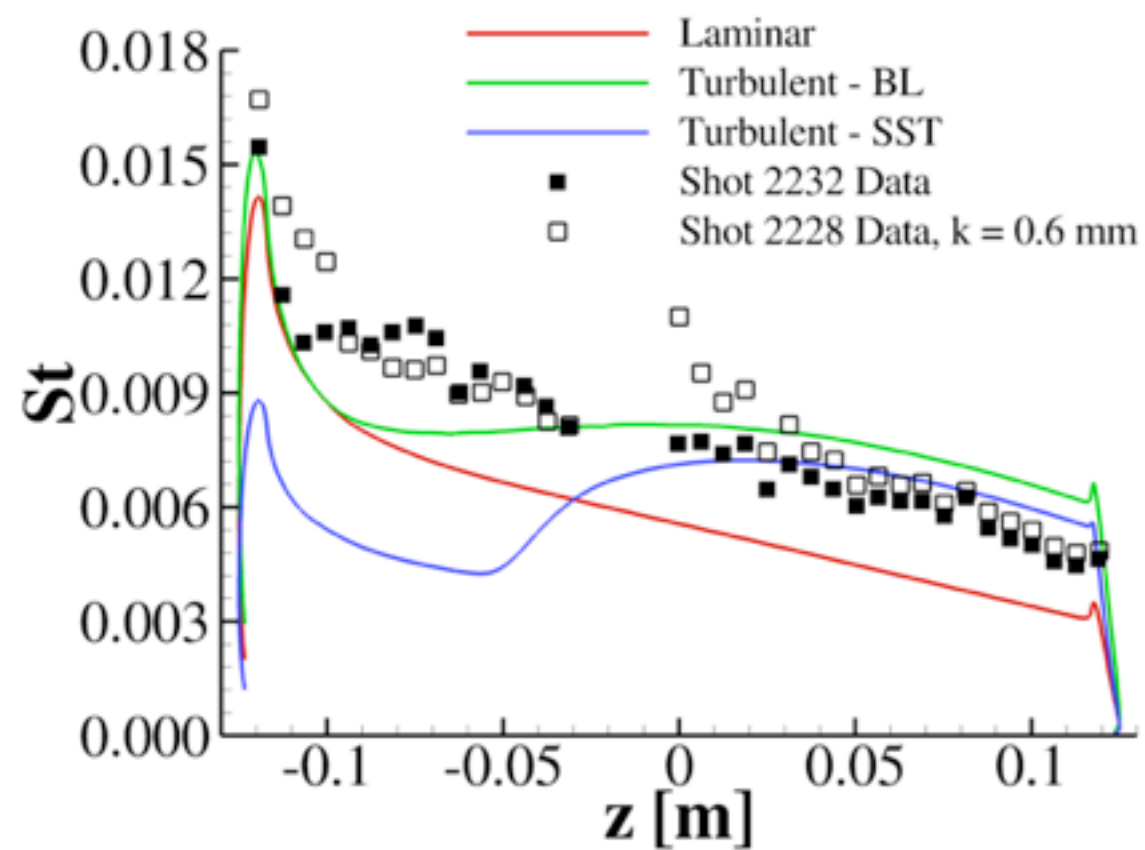


Laminar

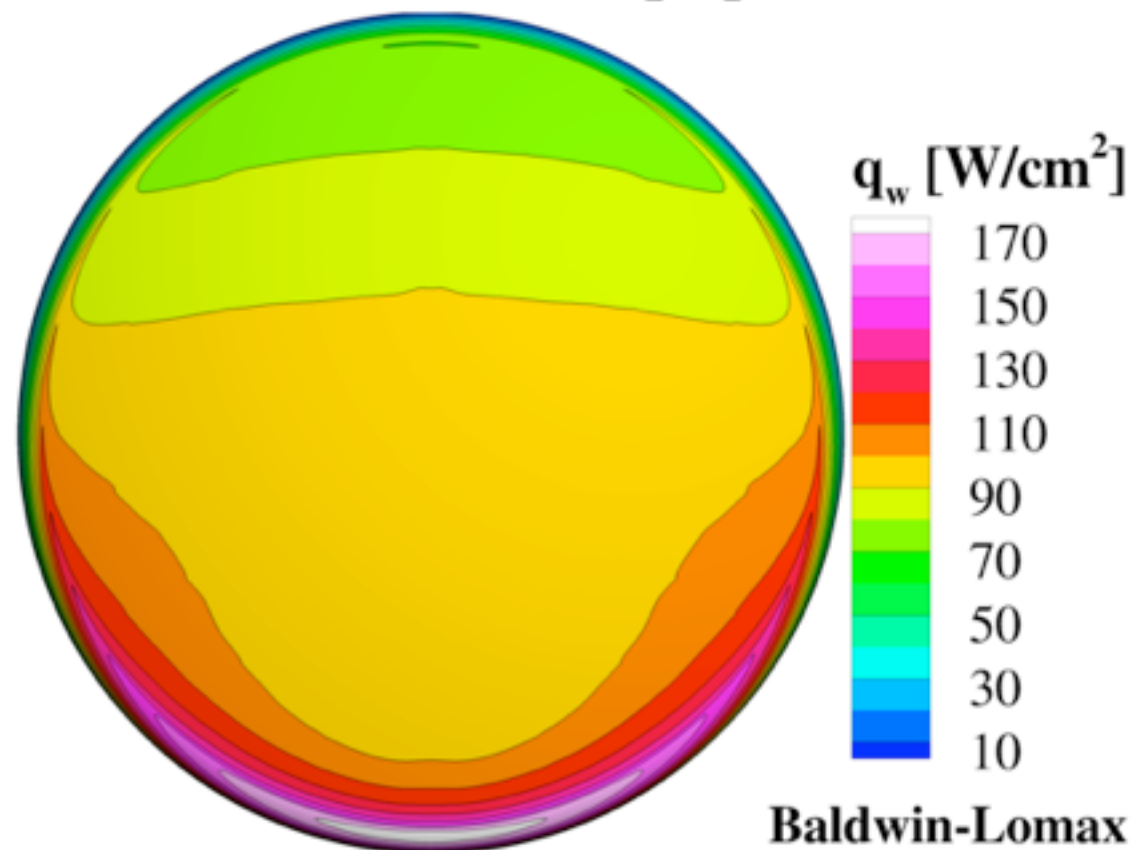
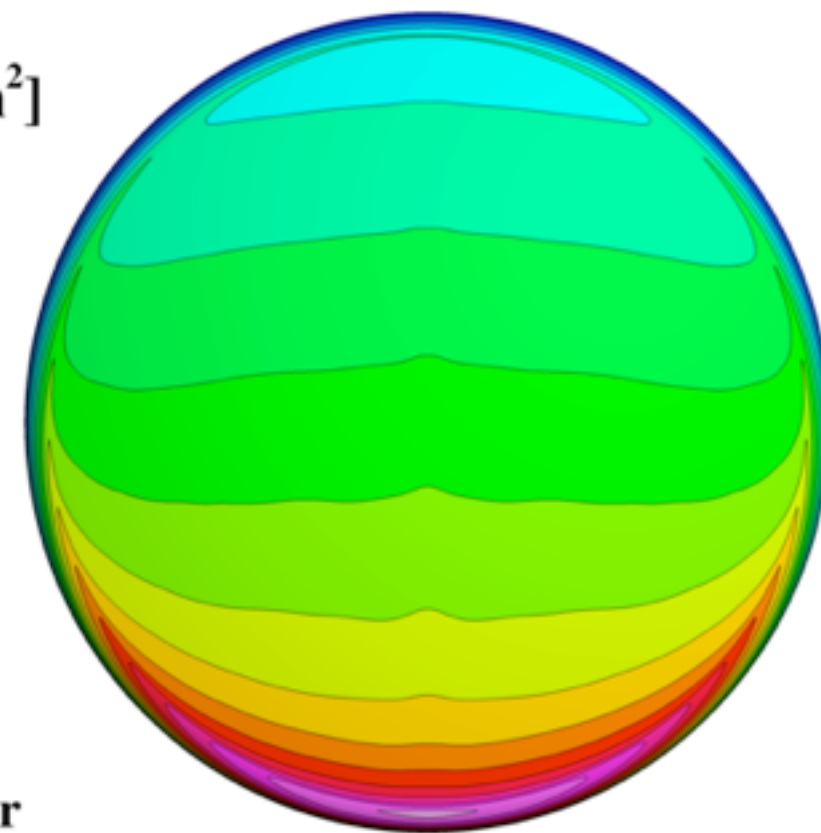


SST

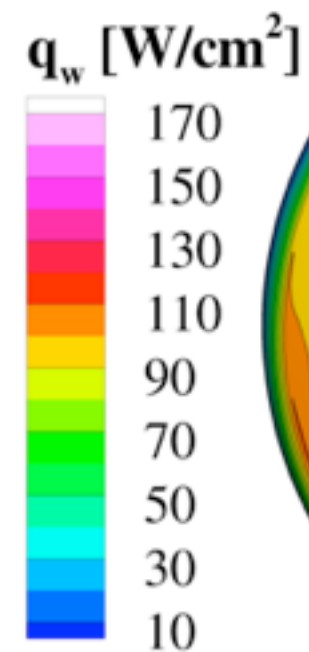




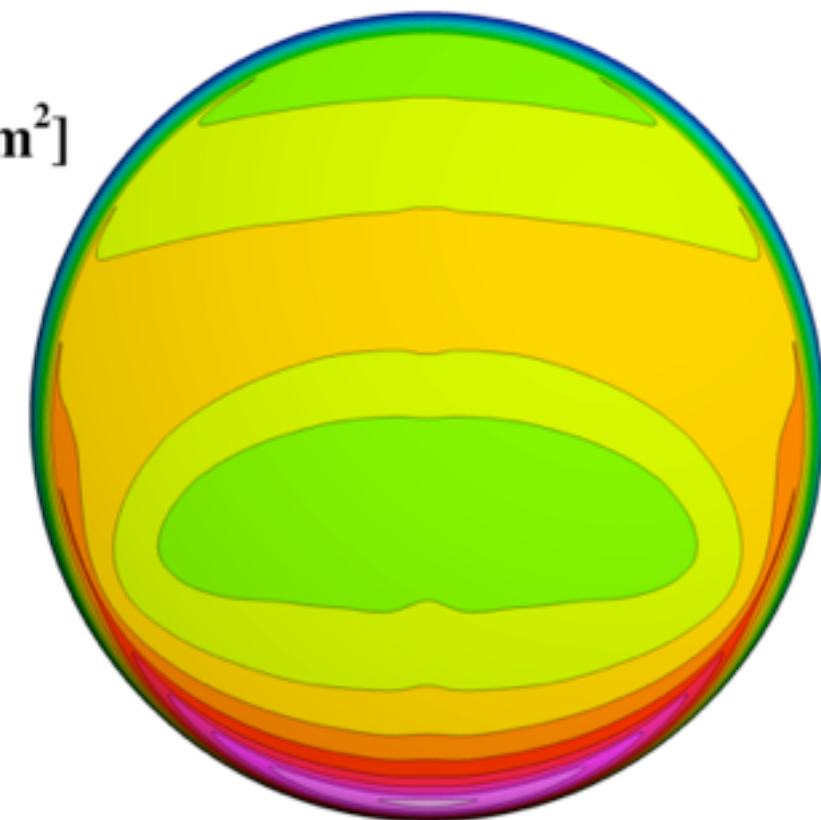
Laminar



Baldwin-Lomax



SST



Shot 2233

